Kepler's Search: Are There Habitable Planets Beyond Our Solar System?

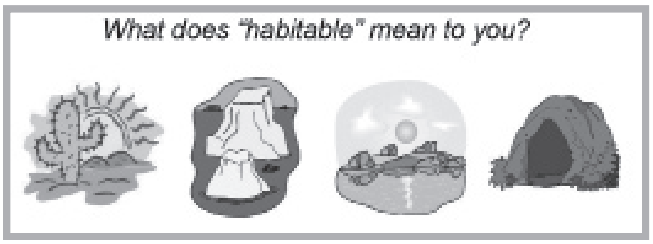
by Dr. David Koch, Deputy Principal Investigator, *Kepler Mission*

Is Earth unique in the universe? How abundant are habitable planets? What constitutes being habitable? NASA's *Kepler Mission* team seeks to answer these questions. The *Kepler Mission* spacecraft, (*Kepler*) launching in 2009, is NASA's first mission capable of finding Earth-size and smaller planets in the habitable zone of other stars in our neighborhood of the Milky Way Galaxy. For the first time in human history, we will know if there are planets capable of supporting life beyond our solar system.

Planets Vary Widely

- What are the differences among the planets in our solar system?
- How do their sizes compare? their masses? their temperatures? their surfaces?
- Why would one of the planets be more or less habitable than another?
- How is Earth uniquely different from all the others?

If you could create a planet where you would be able to survive, what would be the important features of the planet?

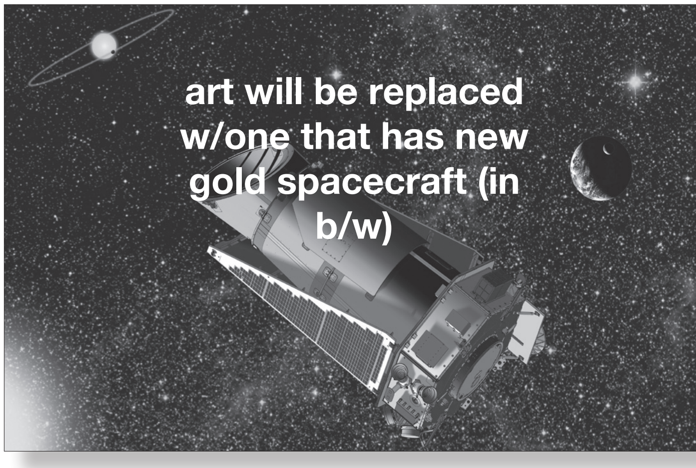


Note: we are not talking about whether there are burger joints, TVs, iPods or other technological conveniences. We are talking about the basic requirements for life as we know it.

Two fundamental characteristics for a habitable planet stand out:

1. The first is the temperature of the planet: What happens to water on the surface of a planet if the planet is too close to its star? Or too far away from its star? What does this tell you about the orbit of a planet?

2. The second is the mass or size of the planet: What must the size or mass of a planet be for it to have a life-sustaining atmosphere? Consider the following: If the mass is too small, then there is not enough gravity to hold onto an atmosphere. The Moon, Mercury and Mars are all too small to have a life-sustaining atmosphere. On the other hand, if the mass of a planet reaches about ten times the mass of the Earth, it has enough surface gravity to hold onto the most abundant and lightest elements in the universe, hydrogen and helium, and grow into a gas giant, such as Jupiter or Saturn, Uranus or Neptune. There are many other important features of our Earth's atmosphere: it transports water, it protects us from the Sun's ultraviolet radiation and cosmic rays from space, it contains the oxygen we breath, and acts like a blanket to keep us warm.



NASA/Ames Research Center - Artist's Concept

As in Goldilocks, there is a "just-right" orbit around a star. We call it the habitable zone. And there is a "just-right" size or mass for a planet, between about half an Earth mass to about ten times an Earth mass. Based on these criteria, scientists designed the *Kepler Mission* to be capable of detecting Earth-size planets in the habitable zone of other stars.

Hunting for Earth-size Planets Beyond Our Solar System

We certainly cannot send a spacecraft from star to star to find another Earth. The stars are too far away. And we cannot take a picture of a distant planet even with any of the new powerful telescopes, either from the ground or from space. The problem is that the direct light from a distant star is billions of times brighter than the tiny amount of light reflected from a planet. So we have to be innovative in doing our observing.

The method used by the *Kepler Mission* is to look for the tiny change in brightness in a star that happens when a planet crosses in front of a star. If the orbit of the planet is aligned along our line of sight to the star we will see these passages, called transits, as the planet orbits its parent star. For an Earth-size planet, the change in brightness is very small, about 1 part in 12,000 (the ratio of the area of the planet to the area of the star). The transit lasts for about half a day. And it happens only once an orbit, that is, about once every Earth year, if the planet is in the habitable zone of a star like our Sun.

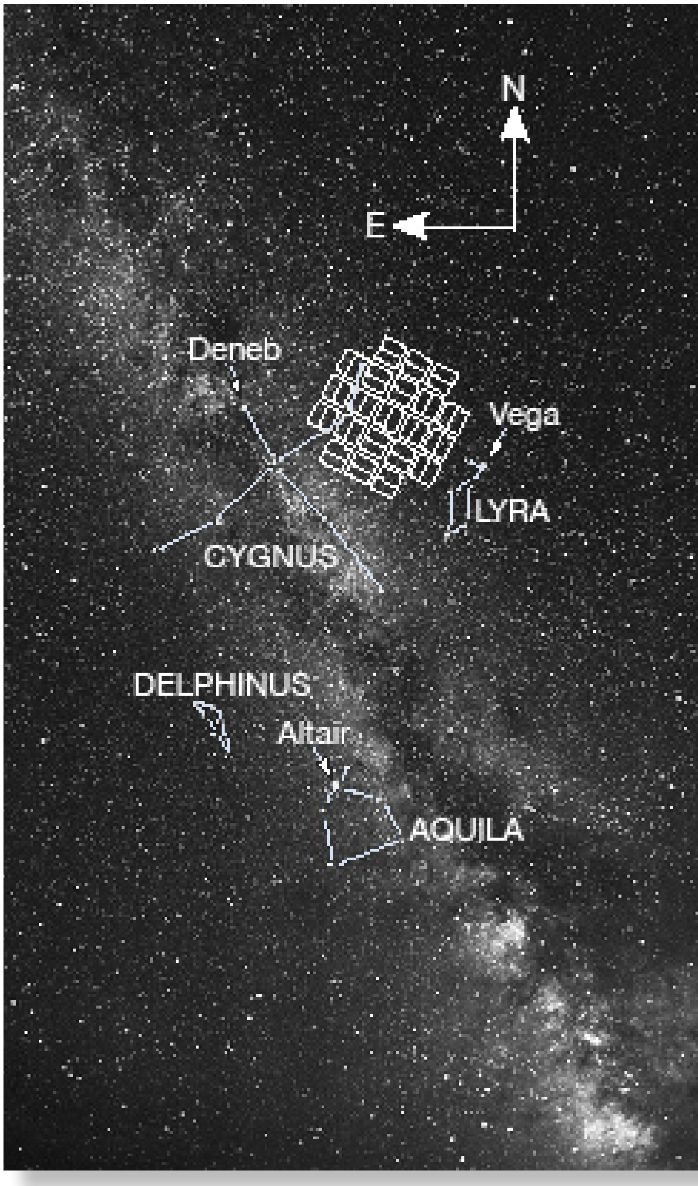
Mission Design

To make these observations, NASA scientists designed a special kind of telescope called a photometer; it's a highly sensitive light meter. It is dedicated to looking for planets as they transit stars. It will be pointed at just one large area in the sky and stare continuously for 3.5 or more years at about 100,000 stars that are similar to our Sun. The *Kepler* telescope has a very large field of view compared to typical astronomical telescopes.

To measure the light from many stars all at the same time, *Kepler* uses detectors called charge coupled devices (CCDs). These are similar to the CCDs found in commercial digital cameras. However, unlike a camera you can hold in your hand, with just a few million pixels (megapixels), *Kepler's* CCD's have 95 megapixels. (Pixel is a term used to refer to the smallest picture element in a digital image.)

The field of view of *Kepler* is a bit larger than the size of your hand held out at arm's length. It is shown on the front of the poster and in the photograph below by all the little rectangles that represent the CCD's.

To conduct the search, *Kepler,* launching in 2009, is orbiting around the Sun, not the Earth, as shown on the front of the poster. The measurements from *Kepler* are radioed back to Earth where scientists analyze them to look for periodic sequences of transits, which are the signatures of planets orbiting other stars.



Milky Way photo by Carter Roberts

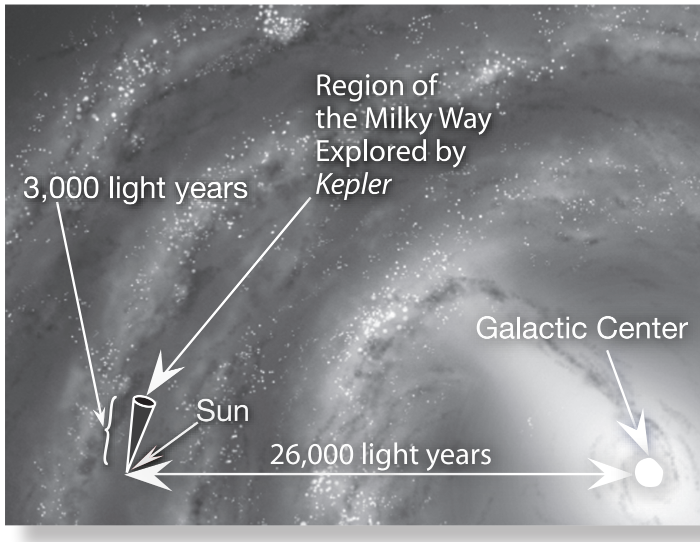
The *Kepler Mission* star field.

Locating the *Kepler* Star Field

Kepler's star field is located in a portion of the Milky Way, shown in the photograph above as the diagonal band of stars, positioned between two of the brightest stars in the sky, Vega and Deneb. Vega and Deneb, along with Altair, form the summer triangle. The three stars of the summer triangle are part of the constellations Cygnus, the swan; Lyra, the harp; and Aquila, the eagle. The field is directly overhead at midnight in late July for mid-northern latitudes. The star field is about 15° across or bigger than your hand held out at arm's length. You can locate the *Kepler* star field on a star map and use a planisphere to determine when and where to look on the night sky. (**http://kepler.nasa.gov/ed/starwheel**)

Distances to the *Kepler* Stars

The illustration below shows our understanding of the shape of our galaxy and the location of our Sun relative to the galactic center. The Sun is about 26,000 light years from the center of the galaxy, less than half the distance from the center to the edge. The cone shows the region of the Milky Way that *Kepler* searches. *Kepler* looks along a spiral arm of our galaxy. The distance to most of the stars for which Earth-size planets can be detected by *Kepler* is from about 600 to 3,000 light years. Fewer than 1% of the stars in the field of view are closer than 600 light years. Stars farther than 3,000 light years are too faint for *Kepler* to observe the transits needed to detect Earth-size planets.



NASA/JPL-Caltech/R. Hurt (SSC)

What We Expect to Discover

Three or more transits of a given star all with a consistent period, brightness change and duration provide a rigorous method of detection and confirmation. The data reveals the planet's:

- Size, from the brightness change and size of the star;
- Orbital period, from the time between transits;
- Orbital size, from the period, Kepler's Third Law, and the mass of the star;
- Temperature, from orbital size and temperature of the star.

From the data, scientists can calculate the fraction of stars that have planets and the distribution of planetary sizes and orbits for many different types of stars. The results will tell us how often planets occur in the habitable zone of other stars.

At the beginning of the mission, planets of all sizes orbiting very close to their stars will be found. After three years, planets will be discovered with orbits of one year in the habitable zone of stars like the Sun. If Earth-size planets in the habitable zone are common, then life may be ubiquitous in our galaxy. On the other hand, if no terrestrial planets are found, then "Earths" may be rare. Learn more at **http://kepler.nasa.gov**